Inhalation Toxicology, 18:925–940, 2006

ISSN: 0895-8378 print / 1091-7691 online
DOI: 10.1080/08958370600835161

informa
healthcare

A Review of the Federal Government's Health Activities in Response to Asbestos-Contaminated Ore Found in Libby, Montana

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Vermiculite ore is a naturally occurring fibrous mineral widely used in various consumer products, such as attic insulation, lawn and garden products, and fireproofing material. While most vermiculite ore and products do not pose a health hazard, the vermiculite mined from Libby, MT was contaminated with naturally occurring asbestos. The federal Agency for Toxic Substances and Disease Registry (ATSDR) has documented a significant number of asbestos-related deaths among Libby residents. Additionally, as part of the ongoing investigation, ATSDR has learned that this contaminated ore was shipped to hundreds of locations around the United States for processing. While the Libby mine is now closed, studies from ATSDR and elsewhere show that people who worked in the Libby mine or vermiculite processing facilities may have been exposed to hazardous levels of asbestos while the facilities were in operation. People who lived or worked near these sites also may have been exposed to asbestos if they came into contact with contaminated vermiculite. Prolonged exposure to asbestos can cause serious and life-threatening health conditions, including asbestosis, lung cancer, and mesothelioma. In response, ATSDR has initiated 10 different activities to help evaluate the potential health effects among Libby residents and populations throughout the United States who might have been exposed to the asbestos-contaminated ore found in Montana. Some of these activities include conducting environmental exposure evaluations, health statistics reviews, community screenings, and disease-specific surveillance. This article presents the various follow-up activities that have been conducted to date by ATSDR and partnering state health departments.

In 1999, the U.S. Department of Health and Human Services (HHS) asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate human health concerns in Libby that were related to asbestos exposure. HHS was acting on requests received from the U.S. Environmental Protection Agency (U.S. EPA) and the Montana Congressional delegation. This petition prompted ATSDR to conduct a thorough review of the history and background of the Libby mine. What ATSDR eventually gleaned from this initial review would lead to further health-related activities, not only within Libby, but at dozens of other sites around the United States.

Vermiculite is mined in various parts of the world. Currently, the predominant commercial mines are in Australia, Brazil, China, Kenya, South Africa, the United States, and Zimbabwe. In the United States, mines are located in Montana, South Carolina, and Virginia (U.S. EPA, 2000). Vermiculite was mined in Libby, MT from the 1920s until 1990. While in operation, the Libby mine may have produced 80% of the world's supply of vermiculite (U.S. EPA, 2006). The Libby vermiculite deposit contained naturally occurring asbestiform fibers, including the amphibole varieties tremolite, winchite, and richterite (Meeker et al., 2003). Contaminated ore from the Libby mine was shipped throughout the United States to more than 200 domestic processing and receiving facilities in different cities. In

Received 17 March 2006; accepted 12 April 2006.

The authors thank the participating state health departments who contributed data for these activities and guided site-specific exposure evaluations.

The views expressed in this article are from the authors and do not necessarily reflect those of the agency.

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1990, the Libby mine and the surrounding mills closed and reclamation began.

Persons who lived in the Libby area during the mine's operation may have been exposed to a variety of amphibole asbestos fibers and similar asbestiform fibers. Those persons include facility employees and those who otherwise came into contact with vermiculite from the facility. Similarly, populations around the United States living near facilities that received Libby ore may have also encountered higher than average levels of asbestos exposure through various stages of processing. The most probable route of human exposure to asbestos-contaminated vermiculite occurred via inhalation, by occupational exposure, by exposure to contaminated clothing of household contacts who were facility employees, or by direct contact with vermiculite or waste products from the facilities. How many people were possibly exposed to asbestos from these vermiculite processing facilities is unknown.

Asbestos exposure has been associated with an increased incidence of asbestosis, lung cancer, mesothelioma, and pleural plaques (ATSDR, 2006). Asbestosis is a chronic, degenerative lung disease caused by the scarring of lung tissue. Mesothelioma is a rare cancer of the mesothelial tissues that line the chest (pleural), abdominal (peritoneal), or other cavities. Asbestos exposure has also been associated with lung cancer and, to a lesser extent, gastrointestinal cancers (esophageal, stomach, colon, and rectal). Asbestos exposure may also result in noncancerous effects of the respiratory system (e.g., pleural plaques, which are a thickening of the membranes that cover the lungs and line the chest cavity).

TABLE 1
Health outcomes evaluated potentially associated with asbestos exposure

Health outcome	ICD[a] code(s)
Malignant neoplasms of digestive organs and peritoneum	150–159
Malignant neoplasms of respiratory and intrathoracic organs excluding nasal cavities and accessory sinuses (includes lung cancer)[b]	165–165
Malignancy without specification to site	199
Nonmalignant respiratory diseases excluding upper respiratory tract infections	480–519
Chronic obstructive pulmonary disease	490–496
Asbestosis[b]	501
Other respiratory	510–519
Breast cancer[c]	174
Prostate cancer[c]	185
Cerebrovascular diseases[c]	430–438

[a] Based upon the International Classification of Diseases Codes–9th Revision [ICD-9] (WHO, 1979).

[b] Known asbestos-related diseases. Unless otherwise specified, the other diseases have weaker associations with asbestos exposure.

[c] Deaths due to other underlying causes were also evaluated to determine the completeness of the data set and were selected for their lack of association with asbestos exposure.

METHODS

Libby, Montana Mortality Review

In 2000, ATSDR—in cooperation with the Montana Department of Public Health and Human Services (MDPHHS)—conducted a mortality review that compared death rates for residents of the Libby area with those in Montana and the United States for selected diseases (Table 1) associated with exposure to asbestos (ATSDR, 2002).

To be considered for this mortality review, persons had to meet all three of the following conditions:

1. An underlying cause of death potentially associated with asbestos exposure.
2. Death occurring during the 20-yr period from 1979 to 1998.
3. Residing in Libby at the time of death.

This analysis period was chosen because it covered the most recent 20 yr of mortality data available at the time during which no overlapping of ICD revisions occurred. It also corresponded to an approximate latency period in which an initial and potential exposure would have occurred and death would be expected.

Once all eligible deceased persons were identified, spatial referencing and analysis of mortality data were conducted using a geographic information system (GIS). On the basis of their residential street address at the time of death, decedents were assigned into six not mutually exclusive geographic areas (Table 2).

Standardized mortality ratios (SMRs) were used to determine if rates in the six geographic areas were higher than those in a reference population. An SMR is the ratio of the sum of the observed deaths in the exposed population (analysis area) relative to the sum of the expected numbers in the exposed population, where the expected deaths are based on mortality rates in a reference population (Checkoway et al., 1989). Montana and U.S. mortality were used as references. Mortality data for the reference populations covered the same 20-yr period and were

TABLE 2
Population estimates for geographic areas of analysis

Geographic areas of analysis	Area (in square miles)	Population (1990 census)
Libby city limits	1.1	2,532
Extended Libby boundary	2.2	3,694
Air modeling	16.0	4,300
Medical screening	25.0	6,072
Libby valley	65.0	8,617
Central Lincoln County	314.0	9,521

obtained from MDPHHS Vital Statistics and the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics.

For this analysis, an SMR of exactly 100 indicates that an analysis area's mortality is equal to that expected from Montana and U.S. mortality rates. An SMR greater than 100 indicates that an analysis area's mortality is higher than expected, relative to Montana and U.S. mortality rates. An SMR less than 100 indicates that an analysis area's mortality is lower than expected, relative to Montana and U.S. mortality rates. Chance variation can cause an analysis area's rates to be higher or lower. The 95% confidence interval (95% CI) was used to evaluate the probability that the SMR may be less than or greater to 100 due to chance alone. A 95% CI with a lower bound value greater than 100 is possible evidence of an elevated rate.

Medical Screening

During 2000–2001, ATSDR conducted two rounds of medical screenings for persons who had lived, worked, or engaged in recreational activities in Libby, MT for 6 mo or more before December 31, 1990. The project was designed to assess whether residents showed evidence of lung abnormalities that may be related to asbestos exposure. Screening included chest x-rays for those over age 18 yr, spirometry, and an in-depth interview. More than 7300 people were screened in the two rounds completed in 2001.

U.S. Health Statistics Reviews

In 2001, ATSDR finalized a standardized health statistics review (HSR) protocol for interested state health departments to use in analyzing existing health data of communities near facilities that received Libby ore (Horton & Kaye, 2001). HSRs are statistical analyses of existing health outcomes (e.g., mortality and morbidity) on populations near selected sites of concern. Twenty-five state health departments have taken part in this initiative.

The two primary data sources ATSDR asked states to use were death certificates and cancer registry data. The specific health outcomes evaluated were ones potentially associated with asbestos exposure (Table 3). Participating states were asked to examine the smallest geographic area coded on their death certificates or cancer registry records (e.g., ZIP codes, census tracts, census blocks) where at least one shipment of Libby ore was received. ATSDR obtained the ore shipment and distribution list from U.S. EPA.

To date, the HSR mortality and cancer incidence results from 12 sites (Table 4) across the United States have been published in various ATSDR health consultations (ATSDR, 2005a; LDHH, 2005). Data for the remaining sites not presented will be released by ATSDR in a cumulative report at the end of 2006.

U.S. Mortality Data

Criteria for consideration in the mortality review included dying with an asbestos-related underlying cause of death during

TABLE 3
Mortality and cancer incidence health outcomes evaluated potentially associated with asbestos exposure

Health outcomes evaluated	Mortality: ICD-9 code(s)[a]	Cancer incidence: ICD-O-2 code(s)[b]
Malignant neoplasm of digestive organs	150–154, 159	C150:C218, C260:C269
Malignant neoplasm of respiratory system and intrathoracic organs	161–165	C320:C399
Malignant neoplasm of lung and bronchus[c]	162.2–162.9	C340:C349
Malignant neoplasm of peritoneum, retroperitoneum, and pleura (includes mesothelioma)[c]	158, 163	C480:C488, C384
Malignant neoplasm of mesothelioma[c]	N/A	M-9050:9053
Malignant neoplasm without specification of site	199	N/A[d]
Diseases of pulmonary circulation	415–417	N/A
Chronic obstructive pulmonary disease	490–496	N/A
Pneumoconioses and other lung diseases due to external agents	500–505	N/A
Asbestosis[c]	501	N/A
Other diseases of respiratory system	510–519	N/A
All malignant neoplasms[e]	140–208	C000:C809
Malignant neoplasm of female breast[e]	174	C500:C509
Malignant neoplasm of prostate[e]	185	C619

[a]Based upon the International Classification of Diseases Codes–9th Revision [ICD-9] (WHO, 1979).
[b]Based upon the International Classification of Diseases–Oncology codes, Revision 2 [ICD-O-2] (WHO, 1992).
[c]Known asbestos-related diseases. Unless otherwise specified, the other diseases have weaker associations with asbestos exposure.
[d]N/A, not applicable because either codes do not exist or were not evaluated.
[e]These cancers are not known asbestos-related diseases and were included to evaluate reporting/coding anomalies in the analysis area.

TABLE 4
The 12 U.S. sites analyzed to date, by data source(s) used, area analyzed, population size, and years analyzed

	Mortality			Cancer incidence		
City/state of site	Specific area analyzed	Population[a]	Years analyzed	Specific area analyzed	Population[a]	Years analyzed
Newark, CA	ZIP code 94560	37,861	1989–1998	CT[b] 4446	7785	1986–1995
Santa Ana, CA	N/A[c]	N/A	N/A	CTs 740.03, 740.04, 740.05, 741.03, and 742.00	28,621	1986–1995
Denver, CO	CTs 10.00, 21.00, 13.01, and 13.02	12,557	1979–1998	CTs 10.00, 21.00, 13.01, and 13.02	12,557	1986–1995
St. John the Baptist Parish, LA	N/A	N/A	N/A	ZIP code 70084	7416	1991–2001
Orleans Parish, LA	N/A	N/A	N/A	ZIP code 70117	51,252	1991–2001
Orleans Parish, LA	N/A	N/A	N/A	ZIP code 70126	12,998	1991–2001
Jefferson Parish, LA	N/A	N/A	N/A	ZIP code 70121	40,677	1991–2001
West Chicago, IL	ZIP code 60185	14,796	1979–1998	N/A	N/A	N/A
Dearborn, MI	City limits	89,015	1979–1998	City limits	89,015	1986–1995
Omaha, NE	CT 31	3147	1979–1998	N/A	N/A	N/A
Hamilton, NJ	N/A	N/A	N/A	CTs 18, 19, 28, 29.02, 29.03, 31, 32.01 (BG[d] 3 and 4), and 32.02 (BG 2 and the southern portion of BG 1)	26,762	1979–2000[e]
Marysville, OH	City limits	9656	1979–1998	N/A	N/A	N/A

[a]Population data from the 1990 census of the population (Bureau of the Census, 1992).
[b]CT, census tract.
[c]N/A, data were not analyzed.
[d]BG, block group.
[e]This analysis used the 2000 census population (Bureau of the Census, 2002).

the period January 1, 1979 through December 31, 1998 and residing in the same analysis area as the vermiculite facility at the time of death. This period of analysis was chosen for the same reasons as stated above (see the Methods, Libby, Montana Mortality Review section). California used a different analysis period, however, because full data for the years requested were not available. Data fields queried on decedents (by ICD-9 grouping) included gender, year of death, age at the time of death, and city of residence at the time of death.

U.S. Cancer Incidence Data

Criteria for consideration in the cancer incidence review included being diagnosed with a potential asbestos-related cancer during the period January 1, 1986 through December 31, 1995 and residing in the same analysis area as the vermiculite facility at the time of diagnosis. This analysis period was chosen because it:

- Covered the most recent 10 yr of cancer incidence data available at the time in most firmly established cancer registries.
- Corresponded to an approximate latency period in which an initial and potential exposure occurred and onset of disease would be expected.
- Allowed enough years of data for meaningful analyses.

Louisiana and New Jersey used different analysis periods, however, because full data for the years requested were not available or more years were used to strengthen the analysis power, respectively. The data fields queried on cancer cases (by ICD-O-2 grouping) included gender, year of diagnosis, age at the time of diagnosis, and city of residence at the time of diagnosis.

Data Analyses

Two statistical indices were used to assess the HSR data for the analysis areas: SMRs for the mortality data and standardized incidence ratios (SIRs) for the cancer incidence data. For the SMRs, the expected number of deaths was based upon U.S. rates provided by CDC's National Center of Health Statistics (CDC, 2000). Unlike the Libby analysis described earlier (see the Methods, Libby, Montana Mortality Review section), which

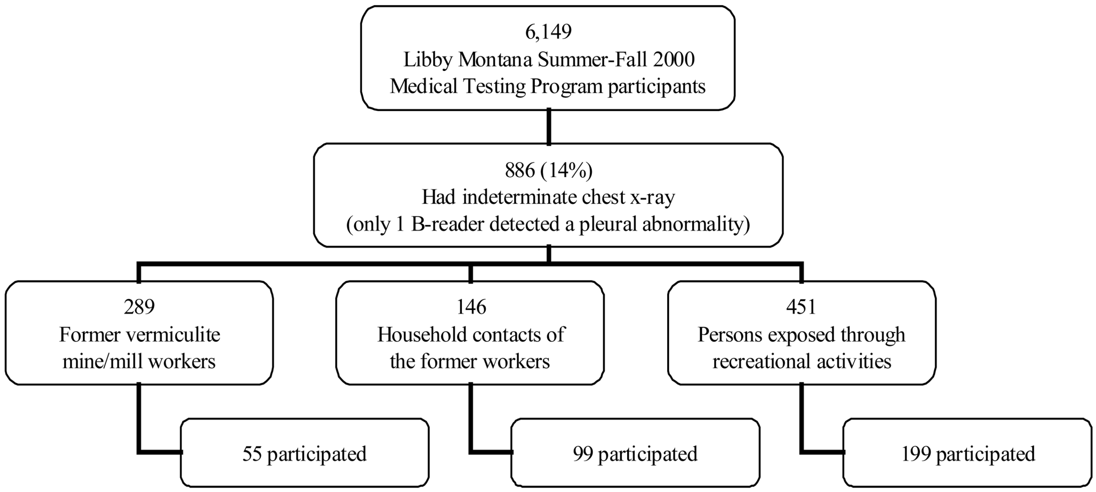

FIG. 1. Eligible study population for computed tomography (CT) scan study.

calculated SMRs based in hundreds, this particular analysis calculated SMRs based in ones. SIRs are calculated the same way as SMRs, except that SIRs use cancer incidence data rather than mortality data. The expected number of cancer cases was based on U.S. cancer incidence rates provided by the Surveillance, Epidemiology, and End Results Program (National Cancer Institute, 2000). Additionally, 95% CIs were used with both indices to assess statistical significance (Breslow & Day, 1987).

ATSDR provided participating states with electronic, preprogrammed Microsoft Excel spreadsheets (e.g., a mortality spreadsheet and a cancer incidence spreadsheet) that would complete all necessary rate calculations. For the Excel program to complete the calculations, states needed to input the number of deaths or cases (by ICD-9 or ICD-0-2 grouping, age group, and gender), along with the 1990 population data of the individual analysis areas. Once the specific data were entered, the spreadsheets automatically calculated the expected numbers of deaths, expected numbers of cases, SMRs, SIRs, and corresponding 95% CIs. Most states used the spreadsheets; some chose to calculate their own SMRs, SIRs, and 95% CIs.

Unless noted elsewhere, population data from the 1990 U.S. Census (Bureau of the Census, 1992) were used to obtain the population size of an area by age group and gender. The 1990 census figures were compiled within the analysis periods of 1979–1998 (mortality) and 1986–1995 (cancer incidence). They provided the most representative estimate of the size and age structure of the analysis populations. In addition, the 1990 census population served as an approximate mid-year point for both analysis periods.

Computed Tomography Study

During 2001–2002, ATSDR conducted an epidemiological study to determine whether high-resolution computed tomography (HRCT) is useful for screening pulmonary abnormalities in people exposed to Libby asbestos (ATSDR, 2001a). Three hundred fifty-three participants from the 2000 medical testing with indeterminate chest radiographs participated in this study. Indeterminate chest radiographs were those in which only one of the three B-readers reported a pleural abnormality. Study participants underwent HRCT of the chest during which they were scanned in both prone and supine positions at full inspiration. All HRCTs were scanned by three expert computer tomography (CT) scan evaluators. All 353 study participants were former vermiculite mine or mill workers ($n = 99$), or people exposed to vermiculite through recreational or other activities ($n = 199$) (Figure 1).

Minneapolis, Minnesota Community Vermiculite Investigation and Worker/Household Study

During 2001–2004, ATSDR funded the Minnesota Department of Health (MDH) to conduct an investigation of community and occupational asbestos exposure from a vermiculite processing facility in northeast Minneapolis. Western Minerals/W. R. Grace (WM/WRG) operated this facility from 1938 to 1989, during which it received more than 100,000 tons of vermiculite ore from Libby, MT. The study population consisted of current residents living in the study area near the facility, former residents, former workers employed at the facility, and family members of workers. Proxy interviews with next of kin were conducted for deceased individuals who met eligibility criteria. The investigations used the following methods:

- Evaluation of Minneapolis property tax records, data collected during U.S. EPA property inspections, and self-referrals to identify residential properties in the study area.
- Door-to-door survey and telephone interviews.
- Visual property inspection for asbestos contamination.

- Examination of deaths certificates of workers at the Minneapolis WM/WRG plant to identify deaths from respiratory cancers or nonmalignant respiratory disease.

Mesothelioma Surveillance

In 2002, ATSDR initiated a pilot mesothelioma surveillance program to determine if exposure to Libby vermiculite contributes to the burden of mesothelioma in the country. The primary goal of this project is to better understand environmental and occupational exposures to asbestos among newly diagnosed mesothelioma patients.

For this project, ATSDR created a protocol and questionnaire to capture potential sources of asbestos exposure among individuals diagnosed with mesothelioma (Melnikova, 2002). ATSDR funded three states—New Jersey, New York, and Wisconsin—to identify mesothelioma cases and interview them by phone. These states are currently collecting data on cases specified by the ICD-O-2 histological code 9050–9053 and are also interviewing next of kin of both living and deceased patients to determine the validity of next of kin interviews.

The questionnaire is being used to collect detailed occupational, residential, medical, family, and smoking histories. Interview data will be entered into a Microsoft Access database and exported into a Statistical Analytic Software (SAS) database for analysis. The collected variables will be summarized using descriptive statistics. GIS techniques will be applied to identify residential exposures. Correlation studies will be conducted to investigate geographic and exposure variable relationships. Logistic regression models, including confounding variables, will be designed to generate odds ratios to investigate the association between vermiculite exposure and mesothelioma. Multiple regression or factor analysis methods will be used to determine risk factors for each of the priority areas identified.

Exposure Evaluations

In 2002, ATSDR—in partnership with state health departments—began conducting detailed evaluations at 28 sites to identify potential past, current, or future exposure pathways to asbestos and to assess the significance of any confirmed exposures (Table 5 and Figure 2).

These 28 sites were chosen for a detailed review, out of the hundreds of other sites around the United States, because U.S. EPA had mandated further action at these sites or because the site was an exfoliation facility that processed more than 100,000 tons of vermiculite from the Libby mine. Data sources included company records, vermiculite shipping invoices from the Libby mine, environmental site assessment and sampling results from the U.S. EPA, sampling results from the National Institute for Occupational Safety and Health, U.S. census records, historical reports from the U.S. Bureau of Mines and the U.S. Geological Survey, aerial photographs, anecdotal information from community members, and site visits by ATSDR and U.S. EPA.

Montana Asbestos Screening and Surveillance Activity

In 2003, ATSDR began health screening in Libby through a program administered by MDPHHS. This program, the Montana Asbestos Screening and Surveillance Activity (MASSA), offers free screenings to people who lived, worked, or played in the Libby area for at least 6 mo before December 31, 1990. The screening includes a face-to-face interview, a chest x-ray, and a spirometry test. MASSA uses a slightly modified version of the protocol ATSDR used previously in Libby (see the Methods, Medical Screening section) (Larson & Spence, 2000). The major changes made to the original protocol are the number of B readers reviewing each chest radiograph (MASSA uses only one B reader due to financial constraints). Additionally, follow-up screenings are offered. MASSA offers follow-up screening matched to risk category, with persons at increased risk of developing an asbestos-related abnormality having a shorter follow-up between screenings.

Tremolite Asbestos Registry

In 2004, ATSDR began a long-term activity of maintaining a registry of persons with potential past exposure to amphibole-contaminated vermiculite from Libby. To be included in the Tremolite Asbestos Registry (TAR), a person must be a former Libby vermiculite worker, a household contact of a worker, or meet the eligibility criteria of either the ATSDR or MASSA medical screening programs. The purposes of the TAR are to:

- Monitor the long-term health of registrants.
- Provide registrants with health education materials.
- Rapidly disseminate information relevant to registrants.
- Facilitate health studies.

ATSDR began enrolling persons in the TAR after attempting to identify and locate all former vermiculite workers and their household contacts. Vermiculite workers, household contacts, and persons who were referred to health care providers during the 2000–2001 medical screening were interviewed by telephone using a survey similar to that used in the ATSDR and MASSA programs (Larson, 2003). In addition, MASSA participants are invited to enroll in the TAR. Types of TAR data include self-reported exposure history, health conditions, and clinical data (B reader interpretation of chest radiographs and spirometry results), when available. Finally, the TAR is being expanded to include workers and household contacts from sites outside of Libby that received contaminated vermiculite. The initial sites to be included are Hamilton, New Jersey and Santa Ana, California.

Marysville, Ohio Study

In 2005, ATSDR funded the first follow-up screening of workers at an exfoliation site outside of Libby (Rohs et al., 2005). Workers at the Marysville, OH, facility were originally screened in 1980 (Lockey et al., 1984). The primary objective

TABLE 5
The 28 sites where ATSDR/state health departments conducted exposure evaluations

City	State	Phase 1 selection criteria[a]	Estimated timeframe for processing vermiculite from Libby[b]	Timeframe from invoices[c]	Tonnage from invoices[c]
Easthampton	MA	U.S. EPA/tonnage	1963–1984	2/66–9/84	183,300
Edgewater	NJ	U.S. EPA	1967–1970s	10/67–10/69	300
Hamilton Township	NJ	U.S. EPA/tonnage	1948–early 1990s	1/66–12/88	317,900
Weedsport	NY	U.S. EPA/tonnage	1963–1991	1/66–12/91	149,800
Beltsville	MD	U.S. EPA	1966–1990	1/66–11/88	93,100
Ellwood City	PA	U.S. EPA	1954–1969	1/66–6/69	9,500
New Castle	PA	U.S. EPA/tonnage	1969–1992	6/69–11/88	172,100
Tampa	FL	Tonnage	1950s–1991	2/66–1/91	112,100
Wilder	KY	U.S. EPA/tonnage	1952–1992	7/53–12/88	222,100
West Chicago	IL	Tonnage	1974–early 1990s	2/74–12/88	274,000
Dearborn	MI	U.S. EPA/tonnage	Early 1950s–1989	1/66–11/88	206,100
Minneapolis	MN	U.S. EPA/tonnage	1936–1989	1/51–9/88	122,800
Marysville	OH	Tonnage	1963–1980	1/67–11/80	429,500
New Orleans	LA	Tonnage	1965–1989	6/66–12/88	148,300
Dallas	TX	Tonnage	1953–1993	1/67–3/93	396,900
St Louis	MO	Tonnage	1944–1988	1/66–9/88	139,500
Omaha	NE	Tonnage	1940s–1991	1/67–1/91	166,500
Denver	CO	U.S. EPA/tonnage	1967–1990	1/67–11/88	103,000
Minot	ND	U.S. EPA	1945–1983	2/67–6/83	16,200
Glendale	AZ	U.S. EPA	1951–1964	Unknown	Unknown
Phoenix	AZ	U.S. EPA/tonnage	1964–1992	5/69–10/92	254,900
Los Angeles	CA	U.S. EPA/tonnage	1943–1979	1/67–7/79	120,200
Newark	CA	U.S. EPA/tonnage	1967–1991	1/67–2/92	337,100
Santa Ana	CA	U.S. EPA/tonnage	1971–1993	12/71–8/88	453,000
Honolulu	HI	U.S. EPA	1954–1983	11/71–4/81	200
Portland	OR	U.S. EPA/tonnage	Early 1950s–1993	1/67–10/91	198,500
Portland	OR	U.S. EPA	1968–1974	12/71–4/74	700
Spokane	WA	U.S. EPA	1940s–1974	1/66–2/74	15,200

[a] Site selection criteria: U.S. EPA = site was listed as a further action site by the U.S. Environmental Protection Agency (U.S. EPA) on the basis of current site conditions (U.S. EPA, 2002). Tonnage = site was listed as an exfoliation facility that processed more than 100,000 tons of Libby vermiculite (U.S. EPA, 2001a).

[b] Best estimate for time frame that the facility handled or processed vermiculite from Libby, MT, on the basis of invoice data and site-specific information.

[c] Information (time frame and associated vermiculite tonnage estimates) from U.S. EPA's database of W. R. Grace & Company shipping invoices for the Libby mine (approximately 1964–1990s) (U.S. EPA, 2001a).

of the follow-up screening was to determine whether cumulative fiber exposure was associated with pleural or parenchymal changes in this worker cohort, while accounting for potential cofactors and confounders.

The recent screening examined worker chest x-rays taken in the past 2 yr. Independent interpretation by three board-certified radiologists (B readers) was administered. A chest x-ray was given an abnormal classification if two or more B readers agreed. Exposure was assessed on the basis of cumulative fibers present (f/cc-yr), employment duration in each department, and industrial hygiene data from the 1980 study.

The outcomes of interest included pleural thickening (unilateral or bilateral thickening, excluding solitary blunting of the costophrenic angle[s]) and parenchymal changes (irregular opacities with a profusion category >1/0). In 2006, additional worker and household contact screenings will be initiated at two other sites that processed Libby vermiculite ore.

RESULTS

Libby, Montana Mortality Review

The most remarkable findings from this mortality analysis were for asbestosis and malignant neoplasm of respiratory and intrathoracic organs, excluding nasal cavities and accessory sinuses (this includes lung cancer). For the 20-yr period reviewed, SMRs for asbestosis in all six geographic areas were

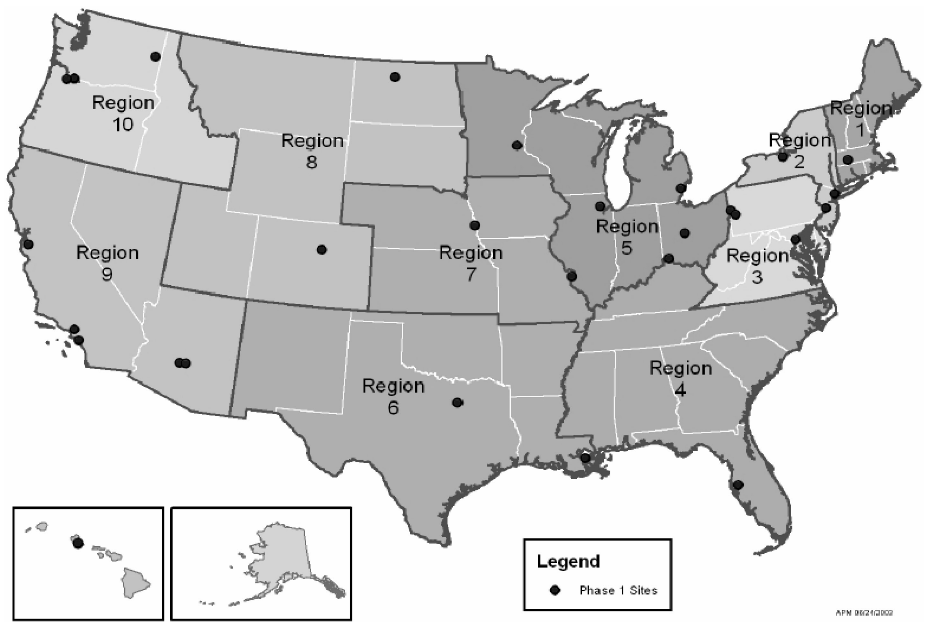

FIG. 2. The 28 sites where the Agency for Toxic Substances and Disease Registry (ATSDR) is evaluating asbestos-related health effects, and their locations within ATSDR/U.S. Environmental Protection Agency regions.

40 to 80 times higher than for Montana and the United States (Table 6).

SMRs for malignant neoplasm of respiratory and intrathoracic organs, excluding nasal cavities and accessory sinuses, were significantly elevated in the Libby Valley and central Lincoln County compared with Montana rates (Table 7).

Mesothelioma mortality was increased but difficult to quantify because reliable statistics on this rare cancer are not available at the state and national levels. Additionally, mesothelioma does not have a specific ICD-9 code from which it can be analyzed independently. Rather, it is placed within the disease grouping *malignant neoplasm of peritoneum, retroperitoneum, and pleura*.

Medical Screening

Of the 7307 total individuals who completed the interview, 6668 participants 18 yr of age or older received chest radiographs to assess the prevalence of pleural and interstitial abnormalities (Peipins et al., 2003). Pleural abnormalities were observed in 17.8% of participants and interstitial abnormalities in $<1\%$ of participants undergoing chest radiography. The risk of abnormalities appeared to increase with increasing age and length of residence in the Libby area. Of the former W. R. Grace (WRG) employees receiving x-rays ($n = 186$), 51% had pleural abnormalities. Among household contacts of workers, prevalence of pleural abnormalities was 26%.

TABLE 6
Standardized mortality ratios (SMR) by geographic area of analysis using Montana and U.S. reference populations, 1979–1998; asbestosis

Area of analysis[a]	Observed	Montana reference SMR	Montana reference 95% CI	U.S. reference SMR	U.S. reference 95% CI
Libby city limits	5	4,084	1,316–9,531	6,355	2,048–14,830
Extended Libby boundary	7	4,730	1,895–9,746	7,495	3,003–15,440
Air modeling	9	4,980	2,273–9,455	7,986	3,644–15,160
Medical screening	10	4,514	2,161–8,303	7,347	3,517–13,510
Libby valley	12	4,221	2,178–7,374	6,948	3,586–12,140
Central Lincoln County	12	3,959	2,043–6,916	6,524	3,367–11,400

[a] All Libby areas were statistically significantly elevated ($p < .05$).

TABLE 7
Standardized mortality ratios (SMR) by geographic area of analysis using Montana and U.S. reference populations, 1979–1998; malignant neoplasm of respiratory and intrathoracic organs, excluding nasal cavities and accessory sinuses

Area of analysis[a]	Observed	Montana reference SMR	Montana reference 95% CI	U.S. reference SMR	U.S. reference 95% CI
Libby city limits	41	117	84–158	103	74–140
Extended Libby boundary	57	131	99–170	116	88–150
Air modeling	70	131	102–165	116	90–146
Medical screening	87	130	104–160	114	91–141
Libby valley	123	139	116–166[a]	122	101–146
Central Lincoln county	124	131	109–156[a]	114	95–136

[a]Statistically significantly elevated ($p < .05$).

U.S. Health Statistics Reviews

HSR mortality and cancer incidence results from 12 sites across the United States, summarized in Tables 8–10, have been taken from existing published health consultations (ATSDR, 2005a; LDHH, 2005). The results presented are for the sites' total populations and are not stratified by gender. Gender-stratified analyses will be included in the 2006 cumulative report. The empty cells—which denote rates that were within the normal range expected—were included to give a complete picture of all disease groupings that were examined, regardless of whether or not a significant finding was detected.

U.S. Mortality Data

Of the six U.S. sites where death certificates were reviewed, none had statistically significant excesses of known asbestos-related diseases (lung cancer; cancer of the peritoneum, retroperitoneum, and pleura; or asbestosis) for the respective total populations (Table 8).

U.S. Cancer Incidence Data

The results of the HSRs derived from cancer registry records are presented in two separate tables. One consists of all sites (excluding Louisiana); the other consists of only Louisiana data (Tables 9 and 10, respectively). This stratification was done because the Louisiana Department of Health and Hospitals (LDHH) used slightly different disease groupings and population groups in their analysis compared with the rest of the participating states (LDHH, 2005).

TABLE 8
Mortality results for six areas across the United States that received at least one shipment of ore from Libby, MT

Diseases analyzed,[ab] 1979–1998	US areas analyzed: Newark, CA[c]	Denver, CO	West Chicago, IL	Dearborn, MI	Omaha, NE	Marysville, OH
Digestive organs						
Respiratory system						
Lung and bronchus[d]						
Pleura[d]						
Neoplasm unspecified						
Pulmonary circulation	SL[e]	SE[f]		SL		
COPD		SE	SE	SL		
Pneumoconioses						
Asbestosis[c]						
Other respiratory				SL		
All cancer[g]					SE	
Female breast cancer[g]						
Prostate cancer[g]						

[a]Based upon the International Classification of Diseases Codes–9th Revision [ICD-9] (WHO, 1979). See Table 3 for specific ICD-9 codes used.
[b]Empty cells denote rates that were within the normal range expected.
[c]This analysis focused on the period 1989–1998.
[d]Known asbestos-related diseases.
[e]SL = statistically significantly lower than expected ($p < .05$).
[f]SE = statistically significant excess ($p < .05$).
[g]These cancers were included to evaluate reporting/coding anomalies in the analysis area.

TABLE 9
Cancer incidence results for five areas across the United States that received at least one shipment of ore from Libby, MT

Diseases analyzed,[ab] 1986–1995	U.S. areas analyzed				
	Newark, CA	Santa Ana, CA	Denver, CO	Dearborn, MI	Hamilton, NJ[c]
Digestive organs					
Respiratory system					
Lung and bronchus[d]					
Pleura[d]					
Mesothelioma[d]					
All cancer[e]		SL[f]		SL[g]	
Female breast cancer[e]					
Prostate cancer[e]					

[a]Based upon the International Classification of Diseases–Oncology codes, Revision 2 [ICD-0-2] (WHO, 1992). See Table 3 for specific ICD-O-2 codes used.
[b]Empty cells denote rates that were within the normal range expected.
[c]This analysis focused on the period 1979–2000 and used the 2000 census population.
[d]Known asbestos-related diseases.
[e]These cancers were included to evaluate reporting/coding anomalies in the analysis area.
[f]SL = statistically significantly lower than expected ($p < .05$).
[g]SE = statistically significant excess ($p < .05$).

Of the five U.S. sites where cancer registry records were reviewed, excluding Louisiana, none had statistically significant excesses of known asbestos-related diseases (lung cancer; cancer of the peritoneum, retroperitoneum, and pleura; or mesothelioma) for the total respective populations (Table 9). Of the four Louisiana ZIP codes where cancer registry records were reviewed, none had statistically significant excesses of known asbestos-related diseases for the total respective populations (Table 10).

Although not presented in this article, LDHH additionally stratified its analysis by gender and race (all White males, all White females, all Black males, and all Black females). This methodology differed from ATSDR's original protocol, which requested population stratifications of total, male, and female.

TABLE 10
Cancer incidence results for four Louisiana ZIP codes that received at least one shipment of ore from Libby, MT

Diseases analyzed,[a] 1991–2000	ICD-O-2 codes used[b]	Louisiana ZIP codes analyzed			
		70084	70117	70121	70126
All cancers	C000:C809	SE[c]			
Digestive organs	C150–C159, C170–C199, C209–C212, C218, C220–C221, C239–C259, C268–C269, C480–C482, C488				
Respiratory system	C300–C301, C310–C319, C320–329, C384, C339, C381–C383, C388, C390, C398, C399				
Lung and bronchus[d]	C340–C349				SL[e]
Stomach	C160–C169			SE	
Mesothelioma[d]	M9050–M9053				

[a]Empty cells denote rates that were within the normal range expected.
[b]Excludes histology codes M9590–M9989. Additionally, the ICD codes used differ from ATSDR's protocol.
[c]SE = statistically significant excess ($p < .05$).
[d]Known asbestos-related diseases.
[e]SL = statistically significantly lower than expected ($p < .05$). Total observed cases: 268; expected: 318.1; SMR:0.8; 95% CI: 0.8–0.9.

TABLE 11
Crude prevalence of HRCT pleural abnormalities, by exposure category and sex—Libby, MT, 2001

		Pleural abnormality identified		No pleural abnormality identified	
Exposure groups	Number	Number	%	Number	%
Former workers	55	22	40.0	33	60.0
Male	47	21	44.7	26	55.3
Female	8	1	12.5	7	87.5
Household contacts	99	47	47.5	52	52.5
Male	23	9	39.1	14	60.9
Female	76	38	50.0	38	50.0
People recreationally exposed	199	29	14.6	170	85.4
Male	74	9	12.2	65	87.8
Female	125	20	16.0	105	84.0
Total	353	98	27.8	255	72.2

For the known asbestos-related diseases in Louisiana (e.g., lung cancer and mesothelioma), lung cancer was statistically elevated in ZIP code 70084 (Reserve) among Black females (observed cases, 15; expected, 7.2; SIR, 2.1; 95% CI, 1.3–3.1), and ZIP code 70117 (New Orleans) among White males (observed cases, 69; expected, 45.7; SIR, 1.5; 95% CI, 1.2–1.8). Mesothelioma was also elevated in ZIP code 70121 (New Orleans) among Black females (observed cases, 2; expected, 0.04; SIR, 47.4; 95% CI, 8.4–118.2).

Computed Tomography Study

HRCT detected pleural abnormalities in 98 (27.8%) of the 353 participants whose previous chest radiographs were classified indeterminate. Of these 98 people, 69 (70.4%) were either former vermiculite mine or mill workers or household contacts (Table 11). The highest prevalence (47.5%) of pleural abnormalities was in household contacts of former vermiculite workers.

Minneapolis, Minnesota, Community Vermiculite Investigation and Worker/Household Study

MDH found that people reporting exposures fit into one or more of the following categories:

- People who reported direct contact with the processing waste from playing on or around the waste rock piles.
- People who lived within one block of the plant during the years it was operating (1938–1989).
- People who reported having lived on a property contaminated with vermiculite waste rock.

Investigators also evaluated and described working conditions, industrial hygiene sampling data, job tasks, and use of respiratory protection. The investigators have established a comprehensive community health education and communication program. They also have implemented a clear and adequate plan for building the medical capacity of health professionals for recognition, referral, diagnosis, and care of asbestos-related diseases, and plan to conduct screening of northeast Minneapolis community residents in the future.

Mesothelioma Surveillance

The mesothelioma surveillance project is ongoing as the three participating states are currently collecting data. To date, 394 questionnaires have been completed. Preliminary results of the data analysis are anticipated to be completed by the end of 2007.

Exposure Evaluations

To date, 21 of the 28 sites have undergone exposure investigations and health consultation reports have been issued (ATSDR, 2005a). Findings thus far indicate that exfoliation facilities received approximately 95% of the vermiculite shipped from the Libby mine from 1964 through the early 1990s (U.S. EPA, 2001a, 2002). Exfoliation is a commercial process that uses intense heat to vaporize water molecules in the layers of vermiculite and expand it into low-density, accordion-like nuggets. The unexpanded vermiculite shipped from Libby contained 0.3–7% asbestos (Atkinson et al., 1982). The waste rock generated from exfoliation processing contained 2–10% asbestos (U.S. EPA, 2001b, 2003a).

In general, vermiculite exfoliation facilities were small-scale, dedicated operations employing 10–50 people and operating 1–3 exfoliation furnaces (U.S. EPA, 2003a). Each furnace was capable of processing approximately 2,000 pounds of vermiculite per hour; some of the facilities operated three shifts, seven days wk (U.S. EPA, 2003a).

Industrial hygiene monitoring and engineering sampling data available from exfoliation facilities during the 1970s and 1980s indicate indoor airborne fiber levels up to two orders of magnitude higher than the current Occupational Safety and Health Administration permissible exposure limit of 0.1 f/cc (ATSDR, 2005a). Although the data sets for each site are not extensive (Figure 3; ATSDR, 2005b), a fairly consistent exposure profile for this period emerges when the available data are aggregated for a number of these sites.

With a few exceptions, ATSDR did not find evidence of industrial hygiene practices (e.g., changing clothes and showering before leaving work or wearing uniforms that were laundered at work) that would minimize take-home contamination. Without such practices, these workers probably inadvertently exposed their household contacts to fibers on their work clothes, hair, and shoes.

At one site in Minneapolis, MN, 655 people reported that they played in or around waste rock piles at the exfoliation facility when they were children (MDH, 2004). At other sites, it appears that this practice was limited, with some reports of people taking

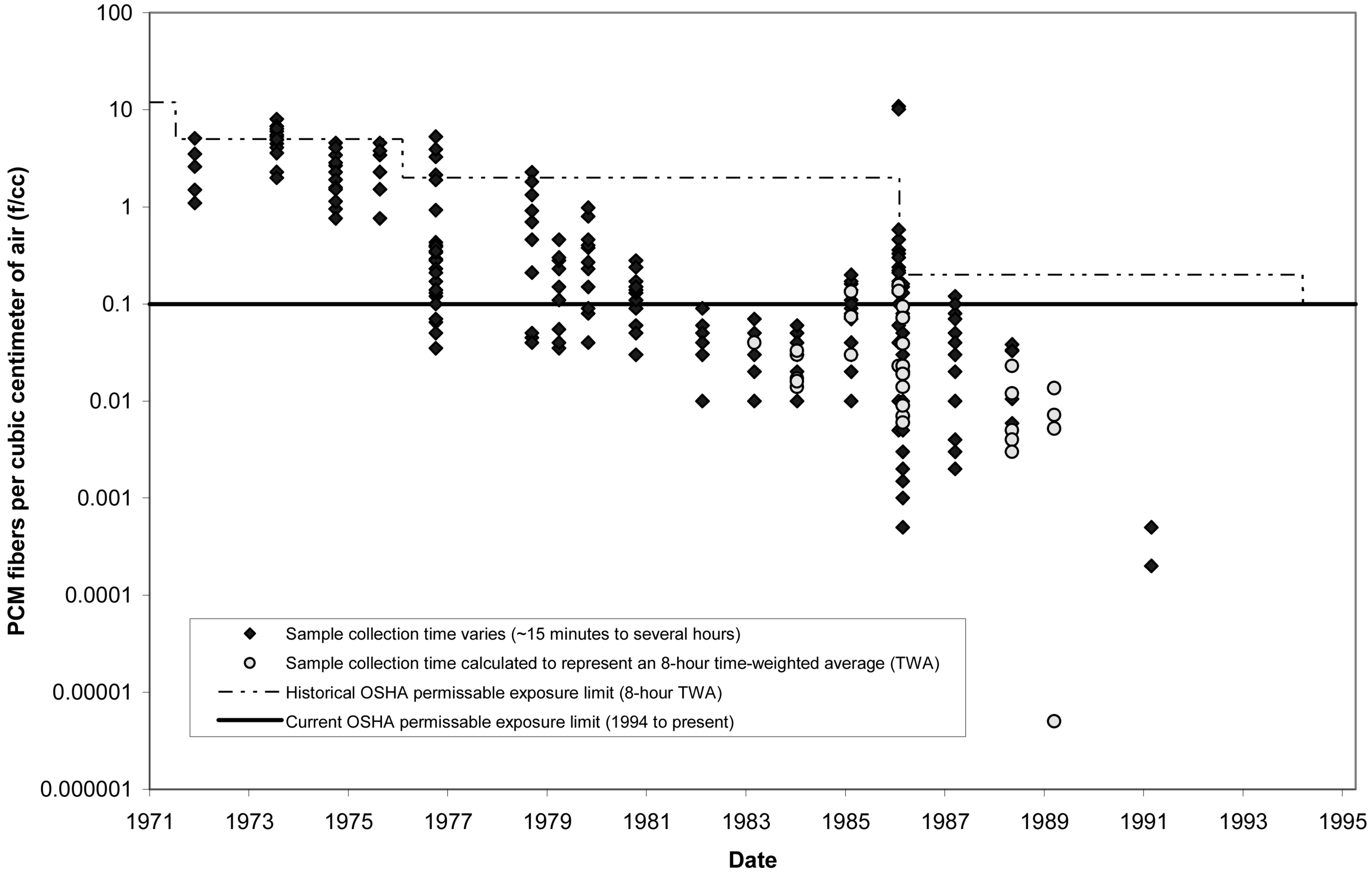

FIG. 3. Representative airborne phase contrast microscopy (PCM) fiber concentrations over time: personal sample data ($n = 286$) at the Texas Vermiculite/W. R. Grace Dallas facility, Dallas, TX. From W. R. Grace Industrial Hygiene Surveys, 1972–1991. Personal samples were collected within a worker's breathing zone. Fiber concentrations were determined by PCM using counting rules similar to NIOSH method 7400.

waste rock home and children playing on waste rock piles and in or near rail cars containing vermiculite (ATSDR, 2004a, 2004b, 2005c).

Montana Asbestos Screening and Surveillance Activity

As of December 31, 2005, MASSA had performed 2475 screenings. Of these, 1893 (76%) were follow-up screenings of persons who participated in the 2000–2001 medical screening. MASSA is expected to continue offering free screening for the foreseeable future. A report summarizing the results of the MASSA screening is anticipated by the end of 2006.

Tremolite Asbestos Registry

Nearly all MASSA participants have consented to be enrolled in the TAR. Apart from MASSA participants, however, ATSDR enrolled 1805 persons in the TAR by telephone. Of these, 724 (40%) had participated in the 2000–2001 ATSDR screening. ATSDR expects to maintain the TAR for the foreseeable future. ATSDR and MDPHHS anticipate releasing a joint report summarizing TAR data by the end of 2006.

Marysville, Ohio Study

The first 236 participants who completed the x-ray and interview were the focus of this preliminary analysis (Rohs et al., 2005). Of the original cohort, 84% (433) were alive. The median age was 58 yr and median latency from hire was 35 yr (range 24–55 years). The findings indicate that a significant trend of increasing pleural changes was detected in relation to increasing cumulative fiber exposure (Table 12).

TABLE 12
Range of cumulative exposure and percent of workers with pleural changes, by worker quartiles

Worker quartile	Number of workers	Rangke if exposure (fiber/cc-yr)	Pleural change[a] % (n)
1st	59	0.0007–0.361	5.1 (3)
2nd	59	0.362–1.042	22.0 (13)
3rd	59	1.043–2.564	33.9 (20)
4th	59	2.565–28.112	44.1 (26)
Total	236	—	26.3 (62)

[a]Significant trend at $p < .0001$.

The overall prevalence of parenchymal changes was 2.5% (6/236). Each of the 6 participants with parenchymal changes was more than 60 yr old and in the 90th percentile of exposure (>10 fiber/cc-y).

DISCUSSIONS AND CONCLUSIONS

Libby Mortality Review

ATSDR found significant excesses for both malignant (lung cancer) and nonmalignant respiratory mortality (asbestosis). Occupational exposure at the mine and milling facility was likely the cause for most of these deaths because many decedents were former workers—some of whom were employed at the facility for long periods of time. However, significant increases in asbestos-associated pleural abnormalities were also found among current Libby residents, most of whom were never associated with the vermiculite mine and milling facilities (Peipins et al., 2003).

Limitations of this analysis include the effects of population migration, smoking prevalence, diagnostic bias, and the general problems with relying on death certificate data to assess asbestos-related mortality.

Medical Screening

The factors most strongly associated with pleural abnormalities were being a former W. R. Grace (WRG) worker, being older, having been a household contact of a WRG worker, and being a male. Environmental exposures and other nonoccupational risk factors were also important predictors of asbestos-related radiographic abnormalities. The principal limitations of these analyses are selection and observer biases.

U.S. Health Statistics Reviews

Thus far, the findings from participating state health departments around the United States do not reveal elevated rates of asbestos-related diseases to the extent found in Libby, MT. In fact, none of the 12 U.S. sites where death certificates and cancer registry records were reviewed had any statistically significant excesses of known asbestos-related diseases for the respective total populations.

Overall, there were some excesses of other diseases found in the HSRs (i.e., chronic obstructive pulmonary disease [COPD], pulmonary circulation diseases, and other diseases of the respiratory system); however, these diseases have weaker associations with asbestos exposure, if any. These outcomes were examined because potential asbestos exposure may have aggravated these conditions and led to premature mortality. In addition, those who died could have been misdiagnosed with these diseases not directly associated with asbestos exposure (i.e., COPD), thus increasing their numbers.

There are limitations in using existing data sources to examine the relationship of the occurrence of chronic diseases (e.g., cancer) and an environmental exposure. Some of the major limitations in this analysis include exposure misclassification, large study areas, small numbers of events, underreporting of cancer cases, miscoding of deaths, population migration, and other confounding factors. Therefore, caution should be used when interpreting these results. The results from these analyses however, may be useful in generating leads for further investigations and future analyses for sites with noticeable asbestos-related health outcomes and significant environmental exposures.

The Four Louisiana ZIP Codes

While excess rates of lung cancer were found in two ZIP codes (70084 and 70117) among Black females and White males, respectively, excess cases due to lung cancer are difficult to interpret because smoking is a potential confounder. Because ATSDR does not know the smoking history of the individuals living in these ZIP codes, it is difficult estimating to what degree, if any, exposure to Libby vermiculite might have contributed to lung cancer development. However, we do know that, in 2004 (the most current year of data available), approximately 23.6% of Louisiana's residents were smokers (CDC, 2006). Smoking is another risk factor that could have contributed to the overall lung cancer disease burden in these ZIP codes.

Additionally, the LDHH did find an excess of mesothelioma among black females, but this excess was based on small numbers and the rates should be interpreted with caution. ATSDR has requested that LDHH follow-up on these cases to attempt to find out if exposure to Libby ore might have been biologically plausible.

Computed Tomography Study

ATSDR's findings indicate that low-dose HRCT can be considered for screening certain former vermiculite mine or mill workers and their household contacts who have had indeterminate chest radiographs. It also may be useful for diagnosing a suspicious finding on a chest radiograph, particularly in a high-risk person.

HRCT detected pleural abnormalities in 98 (27.8%) of the 353 people tested in the 2000 medical testing program whose chest radiographs were classified indeterminate (only one of the three B reader chest radiograph reviewers had reported a pleural abnormality). Each medical testing participant whose chest radiograph was classified indeterminate was notified that one of the three B readers detected a pleural abnormality. However, overall chest radiograph results for these participants were deemed negative because two B readers classified the radiographs as normal. Therefore, the HRCT scan reversed the negative chest radiograph results for 98 of the 353 people tested in 2000. Among people with indeterminate chest radiographs, former vermiculite mine or mill workers and their household contacts may be at highest risk of having asbestos-related pleural abnormalities detected on HRCT.

Several previous studies show that a conventional CT is superior to chest radiography in detecting asbestos-related pleural abnormalities (Tiitola et al., 2002; Oksa et al., 1994; Neri et al., 1994; Kim et al., 2001). HRCT was chosen for this study over conventional CT because HRCT detects asbestos-related pleural abnormalities more frequently than does conventional CT (Aberle et al., 1988). Previous screenings of former construction, shipyard, and asbestos workers (Aberle et al., 1988; Gamsu et al., 1989; Gamsu, 1991; Koskinen et al., 1996, 1998) and studies that found asbestos-related pleural changes in household contacts of shipyard workers (Kilburn et al., 1985) support the results of this study.

This study has several limitations, including lapses in time between the chest radiographs and the HRCT, participant refusals, study population limited to those with indeterminate chest radiographs, and interstudy–intrastudy comparison difficulties.

Minneapolis, Minnesota, Community Vermiculite Investigation and Worker/Household Study

This investigation recommends cohort follow-up to evaluate cause-specific mortality and cancer incidence and medical screening of exposed groups to measure the occurrence of asbestos-related health outcomes in this population. This investigation's findings could be used by public health agencies in other states where the ore was shipped in responding to concerns in other communities where similar vermiculite waste contamination might have occurred.

Limitations to the findings in this report include unsuccessful attempts at identifying or contacting a large portion of former residents; language barriers; participant recall bias; and a lack of access to, or use of, health care for some participants.

Mesothelioma Surveillance

The results of this pilot project should help to:

- Clarify the exposure pathways and risk factors associated with mesothelioma in the United States.
- Identify populations at risk for mesothelioma development.
- Create prevention strategies.

Limitations of this project could include exposure misclassification, small number of events, and an underrepresentation of cases.

Exposure Investigations

ATSDR identified three groups of people who experienced the most significant exposure to asbestos associated with sites that received vermiculite from the Libby mine:

- Former workers at exfoliation facilities.
- Family members and other household contacts who lived with these former workers.
- Community members (particularly children) who had frequent, direct contact with vermiculite or waste rock from exfoliation facilities in the past.

Actual health risks for individuals vary with frequency, duration, and intensity of exposure (to asbestos); size and type of fibers to which a person was exposed; and personal risk factors (smoking, history of lung disease, and genetic susceptibility) (ATSDR, 2001b). Additional studies exploring exposure histories, risk factors, and prevalence of disease in these sentinel groups would help in refining public health messages and informing scientific research on toxicological models for noncancer health effects and low-dose, intermittent asbestos exposure.

An outreach and education program targeting former workers and household contacts associated with exfoliation facilities is clearly warranted. People who had frequent, direct contact with vermiculite or waste rock at the facilities also should be included in follow-up activities. Health care provider education in these communities and through professional organizations would facilitate improved recognition of atypical risk factors (e.g., those related to nontraditional asbestos-related occupations or nonoccupational exposure) that can contribute to asbestos-related diseases.

This effort is hampered by several factors. Most of the vermiculite exfoliation facilities operated during the time the Libby mine was active, from the 1920s to 1990. Exposure data are not available for much of the time these facilities operated. The industrial hygiene information ATSDR reviewed was from after 1970, when companies began monitoring worker exposure and process emissions in response to environmental and worker safety regulations. Companies also started implementing dust and fiber control measures in response to these regulations. The effectiveness of these technologies is difficult to assess retrospectively. Indeed, many critical factors related to occupational and potential community exposure are difficult or impossible to estimate for quantitative exposure modeling or dose reconstruction analyses.

Additionally, there are unique considerations for sampling, analyzing, and assessing exposure and health risk associated with the types of asbestiform fibers (amphiboles) found in Libby. Most of the current and historical sampling data reviewed, including the data from historical industrial hygiene monitoring, does not include the exact mineralogy and fiber length distribution of the fibers detected. The scientific community generally agrees that mineralogy and fiber length are important factors in assessing the potential for carcinogenic and noncarcinogenic health effects from asbestos exposure (U.S. EPA, 2003b; ATSDR, 2001b).

Montana Asbestos Screening and Surveillance Activity

As medical screening in Libby continues, MASSA continues to be an important part of the long-term public health response in Libby, MT. One likely limitation of a study that is based on MASSA data is selection bias.

Tremolite Asbestos Registry

As part of its long-term public health presence in Libby, ATSDR is continuing to enroll participants in the TAR. The TAR data are being used as the basis for several health studies and as a conduit for health education. One likely limitation of any study based on TAR data is selection bias.

Marysville, Ohio Study

The Marysville facility stopped using Libby ore in 1980 and subsequently used ore from elsewhere that reportedly contained no asbestiform minerals. A review of mortality data is currently underway, but the industrial hygiene data are unavailable to confirm, and nonparticipation bias has not yet been assessed.

Preliminary results from the Marysville study are similar to ATSDR's findings in Libby, MT. Pleural changes in the Libby study were detected in 17.8% of participants and 51.0% of former mining and milling facility workers. The prevalence of interstitial changes was $<1\%$, similar to ATSDR's previous findings (Peipins et al., 2003).

Exposure to vermiculite containing asbestos and asbestiform fibers is associated with an increased prevalence of pleural changes among workers with low and higher level exposures. The parenchymal changes are in those with the highest exposure. The public health implications of these preliminary findings are important in view of national distribution of the Libby ore.

All ATSDR Health Activities

The Libby mine was in operation for approximately 70 yr, but only now are we beginning to understand the true environmental and public health implications this asbestos-contaminated ore caused in Libby and around the United States. The health activities being undertaken by ATSDR and partnering state health departments are an important first step in uncovering the resulting environmental contamination that occurred and the prevalence and degree of asbestos-related abnormalities among current and former Libby residents and those outside of Libby who might have been affected.

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